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THE OASIS SOIL TYPE CHANGE AND ITS FRACTAL IN MANASI RIVER BASIN BETWEEN 1987–2006, ARID NORTHWESTERN CHINA

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Abstract. During the past 20 years, great landscape changes took place in the northwest of China. Landscape change resulted in soil type transformations. This paper discusses the changes and fractal of soil types in oasis. In order to do it, the soil type maps of Manasi River Basin in 1987 and 2006 were used. 13 types of soil and 2 types of land-use were classified and analyzed in the study area. Results indicated many variations in characteristics. Firstly, all soil types underwent remarkable changes from 1987 to 2006 in the study area: the identified changed area was about 30% or 6506.33 km^2. Secondly, in comparison with 1987, in 2006 2/3 of the area's soil types increased, while 1/3 decreased. Rapid expansion of Aquicambids (415.28 km^2), and rapid decrease of Petrocambids (797.05 km^2) and Aquisalids (415.93 km^2) were the noticeable findings. Furthermore, Haplocambids obtained largest gains from other soil types, while Petrocambids lost largest area to other types. Additionally, the fractal relationship objectively existed between the perimeter and area of soil patches. The fractal dimension of Aquisalids, Petrocalcids and Ustifluvents became higher and their shapes became more complex during this period. The stability index was higher in 2006 which indicated that the spatial structure of soil type was more stable than in 1987. These chaotic and occasional changes were largely caused by human activities and natural conditions. Consequently, environmental managers should pay more attention to soil changes in the arid and semiarid region.

Keywords: fractal dimension, human activities, soil change, landscape change.

1. Introduction

Land use/cover is a focus of global environmental change (Turner *et al*. 1994). It is also an integrated reflection of various soil type transformations. Variation of soil drainage and soil texture within a region has proven to be a suitable predictor for plant species richness (Honnay *et al*. 2003, 1999; Burnett *et al*. 1998), water and soil quality degradation (Dalal, Mayer 1986) and land degradation (Mundia, Aniya 2006; Luo *et al*. 2005). Many factors can alter the soil type and landscape. Human activities and environmental conditions are the two main reasons for the soil type change (Barbosa *et al*. 2009; Wickham *et al*. 2000; Liu *et al*. 2004). Understanding the mechanism of soil type change variation is conducive to the analysis of the environmental and land use changes (Veteikis, Jankauskaitė 2009). There are many soil types, whereas each soil type contains a great deal of patches in a region. Landscape ecology provides an integrated approach to study the relationship between soil type patches and dynamics in the environmental conditions (Gustafson 1998). Various landscape indices (Jaeger 2000; Baker, Cai 1992; Wu 2000) can be used to describe the characteristics of the soil types. Fractal dimension is the quantification of soil patch shape (Wu 2000). The research on soil type complexity will contribute greatly to our understanding of the soil stability and its reaction to human activities and environmental factors. In recent decades, land use/cover dynamics and soil type characters have received more attention internationally (Coppin *et al*. 2004; Kliment'ev *et al*. 2007; Zhou, Li 2008; Graham, O'Geen 2010; Jankauskaitė, Veteikis 2010; Jennifer *et al*. 2009), but soil type dynamics studies have not received enough attention from scientists (Webster 1985; Jonathan *et al*. 1999; Yu *et al*. 2010). In the recent decades, the economic conditions improved dramatically in the study area. The gross output value of industry and agriculture reached 140.6×10^8 RMB in 2006, which was 15 times more than that in 1987. With the rapid industrial and agricultural development in Manasi River Basin, the local soil types underwent great changes. Therefore, it is important to study the changes of soil types in this area.

Xinjiang of China, an extremely arid region, is located in the middle of Eurasia. The specific morphologic character is that two basins (Junggar Basin and Tarim

Basin) lay among the three mountains (Altay Mountain, Tianshan Mountain and Kunlun Mountain). This morphologic character develops oases, the unique intrazonal landscapes in arid and semi-arid regions. Unlike other regions, the local landscape structure and environmental changes are mainly manifested by the desert-oasis-river landscape type and highly depend on water sources (Qi *et al*. 2007). The surface runoff supplied by mountains rainfall and glacial-snow melt water resources will converge in a small area of oasis and overcome the shortage of water in the desert (Luo *et al.* 2006). The study area, Manasi River Basin, is a typical region of Xinjiang because the regional oasis is one of the largest areas for agriculture and a highly developed industry region. The farmland and living space increased by 8.9% and 1.2% during the past 20 years. It is an activity center of human being and also the representative place for exploring the soil type changes and their stability. In this exploratory study, the soil type transformations and the stability of soil types were analyzed by using two maps of soil type in the study area (Fig. 2, 1987 and 2006).

2. Materials and methods

2.1. Study area

The study area (latitudes 46°00'–44°00'N and longitudes 84°30'–86°30'E) is located in the northern piedmont of Tianshan Mountains, arid northwestern China, with the total area of 22301 km^2 (Fig. 1). Its southern boundary is the east Tianshan Mountains and its north adjoins the Gurbantunggut Desert. The climate is temperate continental arid climate. The annual average surface air temperature is 6.5 °C, and the annual average precipitation and potential average evaporation are 170 mm and 1800 mm, respectively. Most regions of the study area are relatively flat with higher soil potential for agriculture. Soil types mainly include Aquicambids, Halaquepts, Ustipsamments, etc. (Table 1). Plants growing on the cultivated lands include maize (*Zea may L.*), wheat (*Triticum spp.*) and cotton (*Gossypium hirsutum L.*). Previously, the natural landscapes was covered by desert grasslands, saline or alkaline lands. Since 1949, the surface landscapes has transformed into oasis landscape. From 1989 to 2005, the cropland area increased rapidly, expending 8.9% of the total study area (Li *et al.* 2008).

Table 1. Soil types in study area

Code	Soil types	Code	Soil types
11	Aquicambids	71	Petrocalcids
21	Anthracambids	72	Petrocambids
23	Haplocambids	81	Ustipsamments
24	Halaquepts	82	Xeropsamments
32	Plaggepts	83	Ustifluvents
41	Xerumbrepts	91	Saline
61	Aquisalids	1000	Water body
64	Haplosalids		

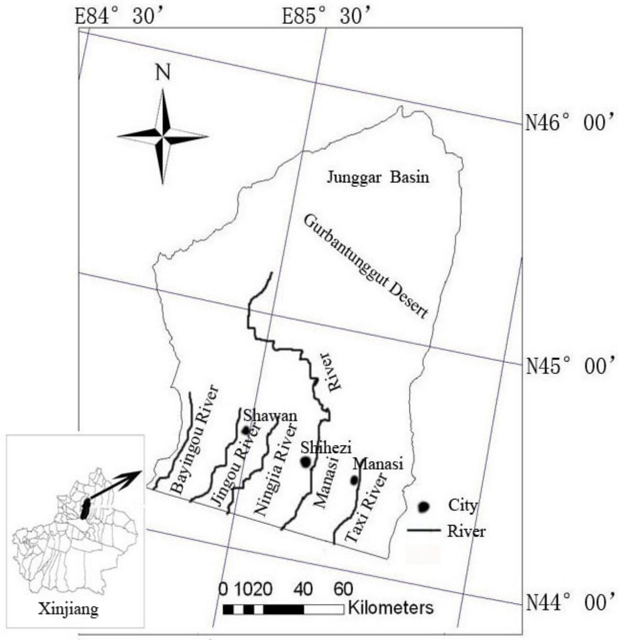

Fig. 1. Location map of study area in arid northwestern China

2.2. Data and method

We developed a GIS database to study the changes and fractal analysis of soil types in Manasi river basin. The soil type data of this study (the original shape files of soil types in 1987 and 2006) were provided by the National Key Technology Program "Study on Ecology-Economic Regionalization and Ecological Compensation in the South of Junggar Basin" (a project of studying the structure of ecology-economic system, the principles and references of regionalization, and the grade of ecological security in Manasi River Basin, Xinjiang). The soil type data of 1987 were generated by automated scanning and manual digitization of the soil maps, which was a product of Second National Soil Survey of China (Soil Survey Staff, 1992). The soil map of 2006, a newly created digital version, was designed in the National Key Technology Program. The scales of the two soil maps (1987 and 2006) were both 1:100 000. Based on these soil type data, the soil type maps of Manasi River Basin (1987 and 2006) were compiled (Fig. 2). According to the American Soil Taxonomy (1992) and the references of Shi *et al.* (2006), the regional soil was classified into 13 soil types and 2 land-use types (Table 1).

GIS is a powerful tool to collect, store, extract, transform and display spatial data, and is necessary in the data use and the study of the landscape dynamic changes (Guo *et al*. 2008). The areas and perimeter values of soil types were measured by using the ArcView GIS version 3.3 (Li *et al*. 2004). In order to define the changes of soil types in the study area, ArcGIS software and its spatial analysis module of Arcmap were used to calculate the transition matrixes (Table 2).

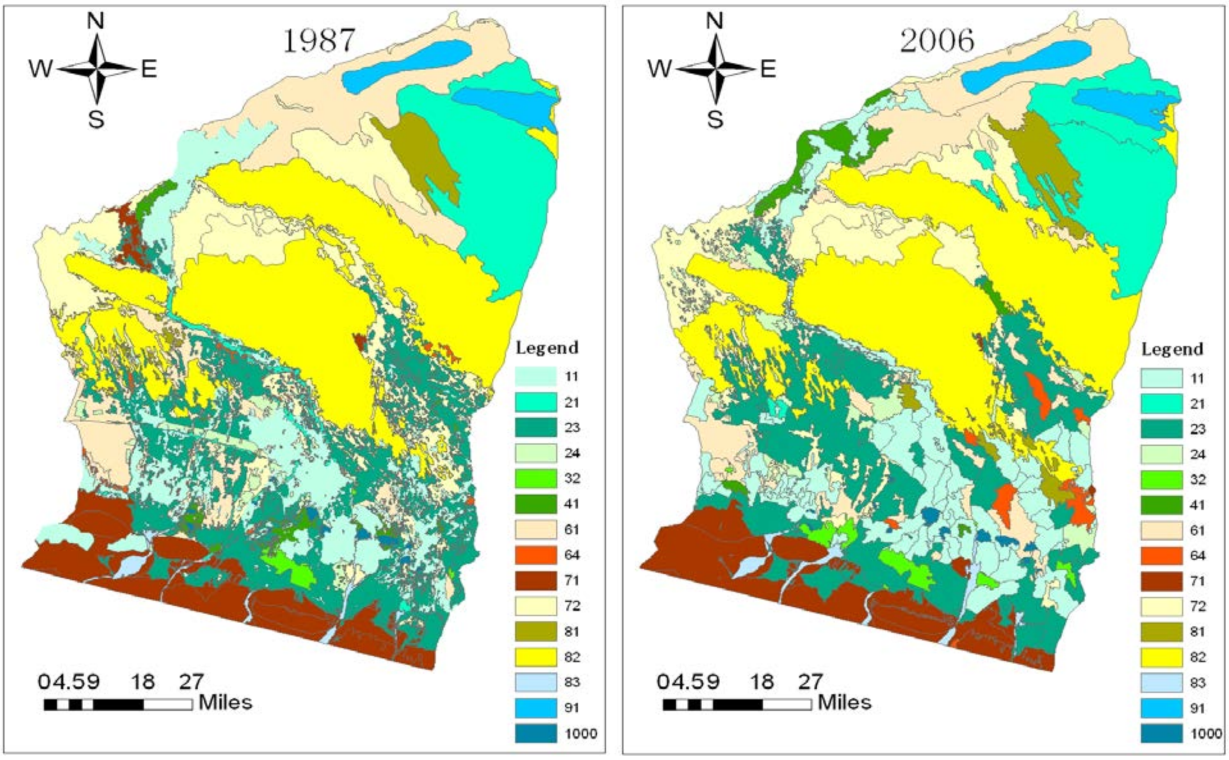

Fig. 2. Soil type maps of 1987 and 2006

Table 2. Transition matrix of soil types from 1987 to 2006 (km^2)

	2006												
1987	11	21	23	24	32	41	61	64	71	72	81	82	83
11	1357.18	2.80	291.17	85.07	5.19	179.73	111.04	28.76	143.79	108.64	15.58	16.78	5.59
21	134.60	1637.17	69.90	10.38	1.60	0.00	55.52	0.00	0.40	15.18	28.76	100.65	4.79
23	610.29	21.97	2172.77	141.39	82.68	18.37	138.59	91.46	44.73	44.33	35.95	18.37	9.19
24	57.12	0.00	163.36	45.13	0.00	1.20	20.37	6.39	13.18	7.19	9.19	3.99	2.00
32	2.00	0.00	5.19	0.00	89.47	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00
41	95.46	0.00	32.75	4.79	13.98	42.74	20.77	4.79	1.20	4.39	0.00	0.40	7.59
61	211.29	37.94	244.84	79.48	13.18	53.92	1564.48	37.54	5.59	142.99	39.14	157.77	0.40
64	15.98	0.00	15.98	5.59	0.00	9.99	3.99	3.99	0.00	1.20	2.80	17.17	0.00
71	13.58	0.00	193.71	29.96	0.00	1.60	3.99	2.40	1488.19	30.75	0.00	5.19	16.38
72	207.69	95.06	291.17	112.63	10.38	17.17	242.04	49.53	3.99	1523.74	83.88	269.20	16.38
81	0.00	17.17	29.96	7.19	0.00	0.00	11.98	0.00	0.00	2.00	325.92	7.19	0.00
82	44.33	32.75	93.86	15.58	0.00	6.79	10.78	0.00	0.40	229.66	25.16	4839.61	0.00
83	2.40	0.00	5.99	0.00	2.40	0.00	0.00	0.00	16.38	0.00	0.00	0.00	119.02

In addition, in order to identify the main reason for the soil type change in this region, field investigation was carried out in the whole area and the meteorological data and the statistical data of the national economic and social development were collected.

2.3. The fractal dimension and stability index

The certain approach, which has been addressed by Mandelbrot *et al*. (1984) and Xu (2002), is required in order to measure the complexity and stability of a given soil. A defined model for fractal dimension and stability index is expressed as.

2.3.1. *Fractal dimension:*

$$P^{\frac{1}{D}} \propto A^{\frac{1}{2}}, \quad (1)$$

$$\lg P = (\frac{D}{2})\lg A + \lg C, \quad (2)$$

where: P is the perimeter of soil type patch; A is the area of soil type patch; C is a constant; D is the fractal dimension of the given soil type.

2.3.2. *Stability index:*

$$Z = |D - 1.5|, \quad (3)$$

where: D is the fractal dimension of the given soil type; Z is the stability index of the given soil type.

3. Results and discussion

3.1. Soil changes in oasis of Manasi River Basin

The changes of different soil types are one of major indicators showing land-use and landscape changes. Table 3 revealed the area statistics of 13 soil types and 2 landscape types (Water body and Saline) in the study area. In 1987, Xeropsamments was the soil type with the largest area, taking up 23.73% of the study area. Haplocambids was the second, followed by the Haplocambids, Aquisalids and Aquicambids. These five soil types accounted for about 74.46% of the total area and were the major soil types in the study area. The matrix, Xeropsamments, still occupied the largest area, followed by Haplocambids, Aquicambids, Aquisalids and Petrocambids in 2006. The areas of other soil types were relatively smaller (generally less than 5% of the study area) on the two period of observations.

Between 1987 and 2006, phenomenon can be revealed from the results of the soil type changes. Firstly, by comparison with the 15 types in 1987, the areas of 10 types increased, while 5 types decreased in 2006. The second was the relative increase of Aquicambids (up from 2351.38 to 2766.66 km^2) and the relative decrease of Petrocambids and Aquisalids, the latter two had decreased 797.05 km^2 and 415.93 km^2 during the period. The additional noticeable phenomenon was that the areas of Anthrosols (Aquicambids, Haplocambids, Halaquepts and Plaggepts) expanded during the period (Table 3). The increase of Anthrosols implied the positive impact on cropland (the Anthrosols mostly distribute in cropland). The cropland in the study area is mainly based on the irrigation and the increase of Anthrosols, which mean greater demand for water resources. Moreover, agriculture is the major consumption of water resources in the study area. As the Manasi River is almost the sole source of water for this oasis, the increase of Anthrosols is one of dominant reasons that cause serious shortage of water in the lower reach of the Manasi River Basin.

Results of the transition matrix reflect the increase or decrease of each soil type in the study area (Table 2). The soil type change was quite remarkable in Manasi River Basin during this period. From 1987 to 2006, the changed area was about 30% or 6506.33 km^2 of the total study area while the unchanged area was over 70% or 15794.73 km^2 (except for two types, Water body and Saline). Of those changed soil types, Aquicambids and Haplocambids obtained relatively larger areas from other types by 1394.73 km^2 and 1437.86 km^2, respectively, though 994.12 km^2 of Aquicambids and 1257.33 km^2 of Petrocambids transformed into other soil types. However, Petrocambids, Haplocambids and Aquisalids lost relatively larger areas into other types by 1399.12 km^2, 1257.33 km^2 and 1024.08 km^2, respectively.

Of all the soil types, there existed two change styles. The first was the single-converted style, which meant these soil types mainly obtained areas from other types or mostly transformed into other types. Plaggepts, Haplosalids and Ustipsamments belonged to the first style. During 20 years, 129.41 km^2 of Plaggepts changed from other soil type, and only 7.59 km^2 of it were lost into other types; Ustipsamments obtained 240.44 km^2 from other soil type, and only 75.49 km^2 lost to other types. The rest of other soil types were the double-converted style. This meant these soil types not only changed from other soil types in large amount but also converted to other soil types within a large range. For example, Haplocambids and Petrocalcids belonged to the second change style. Between 1987 and 2006, the increased areas of 1437.86 km^2 mostly changed from Aquicambids (291.17 km^2), Aquisalids (244.84 km^2), and Petrocambids (291.17 km^2) to Haplocambids, while the lost area of Haplocambids mainly converted to Aquicambids (610.29 km^2), Halaquepts (141.39 km^2) and Aquisalids (138.59 km^2), respectively. 229 km^2 of Petrocalcids were obtained from other types, and 297.56 km^2 of Petrocalcids converted to the others. The increased Petrocalcids area were mostly changed from Aquicambids (143.79 km^2), Haplocambids (44.73 km^2) and Ustifluvents (16.38 km^2), respectively. The decreased Petrocalcids area mainly converted to Haplocambids (193.71 km^2), Halaquepts (29.96 km^2) and Petrocambids (30.75 km^2), respectively.

Table 3. Areas and proportions of different soil types in 1987 and 2006

	1987		2006		1987–2006
Code	Area (km^2)	Proportion (%)	Area (km^2)	Proportion (%)	Change (km^2)
11	2351.38	10.54	2766.66	12.41	415.28
21	2079.48	9.32	1857.75	8.33	–221.73
23	3457.71	15.5	3609.68	16.19	151.97
24	330.21	1.48	533.83	2.39	203.63
32	99.19	0.44	220.21	0.99	121.02
41	240.57	1.08	327.23	1.47	86.67
61	2597.96	11.65	2182.03	9.78	–415.93
64	74.64	0.33	226.25	1.01	151.61
71	1784.75	8.00	1727.44	7.75	–57.32
72	2907.98	13.04	2110.93	9.47	–797.05
81	400.55	1.80	568.21	2.55	167.66
82	5291.50	23.73	5451.17	24.44	159.67
83	141.13	0.63	183.09	0.82	41.96
91	468.40	2.10	451.02	2.02	–17.38
1000	75.62	0.34	85.96	0.39	10.35

Due to the flat topography, Manasi River Basin is a relatively fertile agricultural land, but it is facing many opposing pressures that can change the soil type. The human activities and natural conditions are the main reasons for the soil type changes in this region. In the recent 20 years, with the population growing in the study area the shortage of food supply and living space became the serious problems for survival of human beings. In order to gain more food and living space, the areas of cropland and build-up land expanded at the same time. The landscape changes have led to the soil type changes. Another reason explaining the soil type changes are the precipitation change. In arid northwestern China water is the most important environmental factor that determines the distribution of vegetation. The cropland area had increased from 3034.86 km^2 to 4235.31 km^2 during the recent 20 years. Owing to the increase of cropland area, the amount of consuming water had increased, but the precipitation could not satisfy the local water demand, because that it only increased by 11.1 mm in the same period. In order to meet the local water requirement, more groundwater had been exploited and used, and thus the groundwater depth dropped. The drop resulted in the decrease of grassland area and forest area. These decrease altered not only the natural conditions but also the soil type. Moreover, the government policy was also an important factor for the soil variations. In the beginning of the West Development Plan, the government reclaimed much land for agricultural use to produce more food (Guo *et al*. 2008). The soil with low productivity was gradually discarded because of the low output. In order to avoid and solve the environmental problems such as soil erosion and desertification, planting of trees and grass are encouraged in the arid northwestern China. The areas of Aquicambids and Halaquepts increase, and the areas of Petrocambids and Aquisalids decrease which are mainly due to the land policy change.

3.2. Analysis of fractal dimension and stability index

According to the patch area and perimeter of each soil type, which were obtained from the soil database in Manasi River Basin, the scatter maps of lgA and lgP were achieved. Figure 3 presents the linear relationship between lgA and lgP by taking Aquicambids as an example. The products of the two and the slope of this linear relationship were considered to be the fractal dimension. There were the total of 13 soil types in Manasi River Basin except for Saline and Water body. Table 4 showed the regression equations and the values of R^2 of 13 soil types. The largest value of R^2 in 1987 was found in Plaggepts, followed by Aquisalids and Haplocambids in 1987. However, in 2006, the largest one was the Plaggepts, followed by Xerumbrepts, Anthracambids, and Haplocambids. The lgA of each soil type was closely correlated with its lgP. The values of R^2 were generally over 0.8 in 1987 and 2006. This meant that a certain relationship objectively existed between perimeter and area of soil patches in Manasi River Basin.

Figure 4 indicated the fractal dimension of each soil type in the Manasi River Basin. The fractal dimension is used to measure the complexity of the given soil type, which is determined by both the area and the perimeter of each soil patch. Significant differences of fractal dimension existed among different soil types.

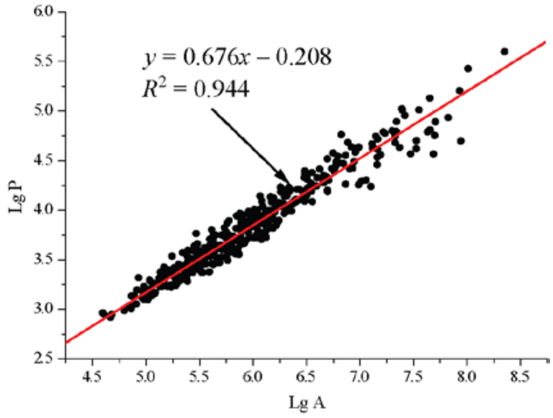

Fig. 3. The linear relationship between lgA and lgP for Aquicambids

Table 4. The regression equation of soil types in 1987 and 2006

Soil code	1987		2006	
	Regression equation	R^2	Regression equation	R^2
11	$y = 0.676x – 0.208$	0.944	$y = 0.547x + 0.521$	0.943
21	$y = 0.673x – 0.142$	0.925	$y = 0.573x + 0.306$	0.949
23	$y = 0.680x – 0.271$	0.967	$y = 0.595x + 0.219$	0.949
24	$y = 0.647x – 0.043$	0.913	$y = 0.633x + 0.012$	0.941
32	$y = 0.612x + 0.075$	0.993	$y = 0.608x + 0.042$	0.985
41	$y = 0.710x – 0.458$	0.947	$y = 0.575x + 0.380$	0.983
61	$y = 0.578x + 0.366$	0.978	$y = 0.607x + 0.143$	0.876
64	$y = 0.775x – 0.826$	0.931	$y = 0.649x – 0.261$	0.846
71	$y = 0.566x + 0.440$	0.92	$y = 0.577x + 0.369$	0.834
72	$y = 0.707x – 0.385$	0.958	$y = 0.650x – 0.101$	0.905
81	$y = 0.588x + 0.279$	0.953	$y = 0.546x + 0.569$	0.911
82	$y = 0.635x – 0.034$	0.957	$y = 0.607x + 0.218$	0.948
83	$y = 0.635x + 0.158$	0.741	$y = 0.667x – 0.152$	0.864

In 1987, the value of fractal dimension was from 1.131 to 1.551. The largest value of fractal dimension was found in Haplosalids, followed by Xerumbrepts and Petrocambids, which meant that the shapes of these soil types were most complex in all soil types. However, the most complex soil type was Ustifluvents, followed by Petrocambids and Haplosalids in 2006.

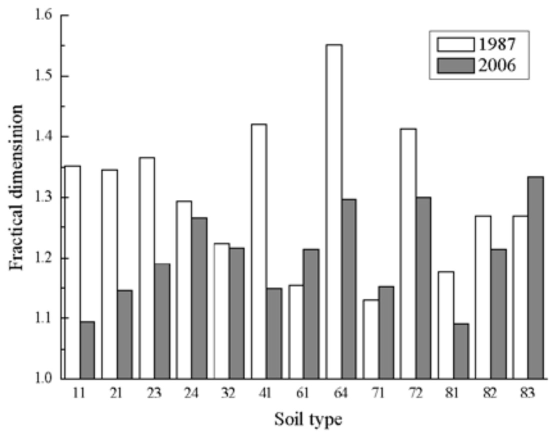

Fig. 4. The fractal dimension of soil type in the study area in 1987 and 2006

From 1987 to 2006, the decreased fractal dimension occupied about 77% of the 13 soil types while the increased fractal dimension was over 20% (Fig. 4). The changes of Aquisalids, Petrocalcids and Ustifluvents were the one-fold. This meant that the shapes of the three soil types were more complex. During the study period, the soil type with the rapidest increase was Ustifluvents, which has expanded 0.064. The second is the Aquisalids, which had expanded by 0.059. More soil types were the two-fold, which meant the shapes of soil types in the study area were becoming simple. In contrast to 1987, there was a significant decrease from 1.421 to 1.150 in the value of Xerumbrepts fractal dimension and from 1.369 to 1.190 in Aquicambids in 2006. They had the same trend as the Xerumbrepts in Haplosalids, Anthracambids, Haplocambids, etc. The results showed the characteristics of typical agricultural oasis and indicated that the biophysical and socioeconomic environment both influenced the soil type.

The stability index measures the spatial structure stability of each soil type. Higher value indicates that the spatial structure of soil type is more stable and not easy to change. The stability indexes of 13 soil types in Manasi River Basin were shown in Table 5. Compared with the stability index in 1987, the value of index became higher in 2006, which indicated that the spatial structures of soil types were more stable than those in 1987. Several findings could be revealed from the results of the stability index for the soil type change (Table 5). The first was the rapid increase of Xerumbrepts, which had expanded more than four fold. The second was the Aquicambids that had increased by 274%. The third was the rapid decrease of Ustifluvents and Aquisalids, which decreased by 72.3% and 83.1%, repectively. The average indexes of number and shape of soil patches are the most important factors influencing the spatial structure of soils (Zhu *et al.* 2005). The human socio-economic activities changed the average indexes of number and shape of soil patches between 1987 and 2006. In other words, the spatial fractal structures of soils were mainly influenced by the human socio-economic activities.

4. Conclusion

Manasi River Basin is an important area in Xinjiang. This paper investigated the changes and the stability of soil types through two soil maps of the study area in 1987 and 2006. The result showed the remarkable soil type transformations from 1987 to 2006, with identified changed area occupying 30% or 6506.33 km^2 of the total study area. By comparison with the 15 types in 1987, the area of 10 types increased, while 5 types decreased in 2006. Rapid expansion of Aquicambids (up from 2351.38 to 2766.66 km^2) and the relative decrease of Petrocambids (797.05 km^2) and Aquisalids (415.93 km^2) were alarming. Of those changed soil types, Haplocambids obtained largest gains from Aquicambids (291.17 km^2), Aquisalids (244.84 km^2), and Petrocambids (291.17 km^2), while the lost area of it mainly converted to Aquicambids (610.29 km^2), Halaquepts (141.39 km^2), Aquisalids (138.59 km^2), respectively. In the recent 20 years, the human activities and natural conditions were the main reasons for the soil type changes in this region. The fractal relationship between perimeter and area of soil patches objectively existed in Manasi River Basin. The fractal dimension of Aquisalids, Petrocalcids and Ustifluvents became higher, which meant the shapes of the 3 soil types became more complexity during this period. The stability index was higher in 2006, which indicated that the spatial structures of soil types were more stabile than that in 1987.

Table 5. The stability index of soil type in 1987 and 2006

Soil code	Stability index 1987	Stability index 2006	Soil code	Stability index 1987	Stability index 2006
11	0.1484	0.4064	64	0.0508	0.2028
21	0.1548	0.3536	71	0.3688	0.3468
23	0.1350	0.3102	72	0.0866	0.1998
24	0.2070	0.2338	81	0.3236	0.4090
32	0.2756	0.2836	82	0.2308	0.2860
41	0.0792	0.3504	83	0.2310	0.1670
61	0.3446	0.2864			

From these results obtained in this study, we must be aware that the human activities are the main factor leading to the soil type variations. These changes have impacted the regional sustainable development and environmental health, so environmental managers should pay more attention to the regional soil changes in the future.

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MANASI UPĖS BASEINO SAUSRINGOJE ŠIAURĖS VAKARŲ KINIJOJE OAZIŲ DIRVOŽEMIO TIPŲ POKYČIAI IR FRAKTALAI 1987–2006 m.

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Santrauka

Per pastaruosius 20 metų šiaurės vakarų Kinijoje įvyko didelių kraštovaizdžio pokyčių, lėmusių ir dirvožemio tipų pakitimus. Remiantis 1987–2006 m. Manasi upės baseino dirvožemio žemėlapiais, aptariami dirvožemio tipų pokyčiai ir fraktalai oazėse. Pasirinktoje teritorijoje išskirta ir analizuota 13 dirvožemio tipų ir dvejopa žemėnauda. Nustatyta daug kintamųjų parametrų. Pirma, tirtõs teritorijos visų tipų dirvožemiai nuo 1987 iki 2006 m. žymiai pakito. Nustatytoji pokyčių zona apima apie 30 % teritorijos, arba 6 506,32 km^2. Antra, palyginti su 1987 m., 2006 m. 10 dirvožemio tipų teritorija padidėjo, o 5 tipų sumažėjo. Sparčiai padidėjo *Aquicambids* (415,28 km^2), sparčiai sumažėjo *Petrocambids* (797,05 km^2) ir *Aquisalids* (415,93 km^2), pokyčiai buvo žymūs. Iš visų kitų pakitusių dirvožemių tipų *Haplocambids* plotai padidėjo daugiausia, o labiausiai, palyginti su kitais, sumažėjo *Petrocambids* plotai. Be to, pastebėta, kad tarp dirvožemio teritorijos plotų ir perimetrų objektyviai egzistuoja fraktalinės sąsajos. Fraktalinės dimensijos *Aquisalids*, *Petrocalcids* ir *Ustifluvents* per minėtą laikotarpį padidėjo, o jų formos tapo sudėtingesnės. Stabilumo indeksas 2006 m. buvo didesnis. Tai rodė, kad erdvinė dirvožemio struktūra mažai pakito, tapo stabilesnė, palyginti nei buvo 1987 m. Šiuos atsitiktinius pokyčius iš esmės lėmė žmogaus veikla ir gamtinės sąlygos. Prieita prie išvados, kad sausojo ar pusiau sauso klimato regionuose kraštotvarkos vykdytojai dirvožemio pokyčiams turėtų skirti daugiau dėmesio.

Reikšminiai žodžiai: fraktalinės dimensijos, žmogaus veikla, dirvožemio pokytis, kraštovaizdžio pokytis.

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